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# A numerical investigation on the fire response of a steel girder bridge

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ABSTRACT

The response of bridges subject to fire is an under researched topic despite the number of bridge failures caused by fire. Since available data shows that steel girder bridges are especially vulnerable to fire, this paper delves into their fire response by analyzing with a 3D numerical model the response of a typical bridge of 12.20 m span length. A parametric study is performed considering: (1) two possibilities for the axial restraint of the bridge deck, (2) four types of structural steel for the girders (carbon steel and stainless steel grades 1.4301, 1.4401, and 1.4462), (3) three different constitutive models for carbon steel, (4) four live loads, and (5) two alternative fire loads (the hydrocarbon fire defined by Eurocode 1 and a fire corresponding to a real fire event). Results show that restraint to deck expansion coming from an adjacent span or abutment should be considered in the numerical model. In addition, times to collapse are very small when the bridge girders are built with carbon steel (between 8.5 and 18 min) but they can almost double if stainless steel is used for the girders. Therefore, stainless steel is a material to consider for steel girder bridges in a high fire risk situation, especially if the bridge is located in a corrosive environment and its aesthetics deserves special attention. The methodology developed in this paper and the results obtained are useful for researchers and practitioners interested in developing and applying a performance-based approach for the design of bridges against fire.



## 1. Introduction

Bridges are a critical component of the transportation system whose loss can result in important social and economical consequences (e.g. [1,2]). While a lot of attention has been paid to understanding and predicting the effects on bridges of accidental extreme load events such as earthquakes, winds, scour, and ship collisions (e.g. [3,4]), fire hazard has got very little consideration as proved by recent literature reviews [5,6]. However bridge fires are a major concern for two important reasons. First, traffic on bridges damaged by fire is usually hard to detour and affects the traffic quality in the region. For example, the collapse of two spans of the MacArthur Maze in Oakland, USA on April 29th 2007 due to a fire resulted in repairs and rebuilding operations costing more than US $9 million [7]. In addition, the closure of the Maze was estimated to have a total economic impact to the San Francisco Bay Area of $6 million dollars a day [8]. Secondly, bridge fires are a real threat as shown by data of a voluntary bridge failure survey, which was responded by the departments of transportation of 18 US states [9]. This survey was conducted in 2011 and collected data related to 1746 bridge failures. Although the vast majority of bridges (1001) collapsed for hydraulic reasons (scour, flood) and 520 collapsed due to collision, overload, or deterioration, 54 bridge collapses were due to fire, and only 19 collapses were due to earthquake (seismic states like California participated in the survey).

Despite the importance of bridge fires, fire safety engineering and structural fire engineering have mainly been concerned with building fire hazards (e.g. [10–15]). However, bridge fires deserve special attention because the fire response of a bridge and a building is different for many reasons including:

(1) *Cause of fire*: bridge fires are commonly caused by collisions (crashing of gasoline trucks and burning of gasoline in the vicinity of the bridge) or construction accidents (such as the ignition of wood scaffolding or wood formwork). On the other hand, building fires are commonly caused by accidental ignition of the fuel sources in the compartment. Since the fuel is different, the fire loads are different.
(2) *Fire loads*: bridge fires are typically petrol fires, also referred to as hydrocarbon fires, which are much more severe than building fires and are characterized by fast heating rates or high fire intensities. Thus, the bridge fire is likely to be much more intense than typical building fire and can reach very high temperatures within the first few minutes of fire exposure.
(3) *Fire protection*: bridge girders typically have no fire protection whereas buildings have active and/or passive fire protection.
(4) *Beam depth*: bridge beams are much deeper than common building beams and therefore more susceptible to web buckling since the webs are more slender.

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